Effect of Fibre Loading on Flexural Properties of Sisal Fibre Reinforced PLA Composites

[1]D. Raj Kumar [2]Gunti Rajesh [3]Atluri V. Ratna Prasad

[1,2]*Department of Mechanical Engineering, DVR & Dr. H S MIC College of Technology, Kanchikacherla, India*
[3]*Department of Mechanical Engineering, V R Siddhartha Engineering College, Vijayawada, India*

Abstract: *The use of natural fibres like flax, sisal, jute, kenaf, etc. as replacement to manmade fibres in fibre-reinforced composites have increased now a days due to advantages like low density, low cost and biodegradability. But the natural fibres have poor compatibility with the matrix and they have relatively high moisture sorption. In this research, sisal fibre reinforced PLA composites have been developed by injection molding technique with varying parameters like fibre loading (5%, 10%, 15%, 20% & 25% by weight) at constant fibre length of 3mm. Then these composite specimens are tested for flexural strength. The results showed that flexural strength increases with increase in the fibre loading. However after 20% fibre loading, strength decreased again. The modulus of the composite also increased with fiber loading in fibre reinforced PLA composite.*

Keywords: *Composite, Natural Fibre, Flexural Properties*

I. INTRODUCTION

With the increased trend for sustainable and environmentally friendly materials, polymer composites industries has lead towards bio degradable polymers from renewable resources such as poly (lactide) acid (PLA). Biopolymers offer environmental benefits such as biodegradability, greenhouse gas emissions, and renewability of the base material. Bio-composites are usually fabricated with biodegradable/ non-biodegradable polymers as matrix and natural fibers as reinforcement. Many lignocellulosic fibers, such as jute, hemp, sisal, abaca etc. are used as reinforcement for biodegradable bio-composites because of their good mechanical properties and low specific mass. Poly lactic acid (PLA) has received much attention of biodegradable polymers. PLA is linear aliphatic thermoplastic polyester, produced from renewable agricultural resources. PLA has properties that are competitive to many commodity polymers (e.g. PP, PE, PVC, PS) such as high stiffness, clarity, gloss, and UV stability. PLA is commonly produced by two methods. It can be commonly synthesized by ring-opening polymerization of lactide. PLA may also be produced by direct polycondensation of lactic acid. Lactic acid, the starting material for PLA synthesis, can be produced by fermentation from a number of different renewable resources. Because PLA has high strength, thermal plasticity, and biocompatibility, it has been used as package materials and other products. However, the physical properties of PLA such as brittleness limit the PLA polymer application. A way to improve the mechanical and thermal properties of PLA is the addition of fibers or filler materials. Combining PLA with natural fibers which are abundantly, readily available such as kenaf, jute, sisal etc. can lead to a totally bio degradable composite made only from renewable resources.

Fibres obtained from the various parts of the plants are known as vegetable fibres. These fibres are classified into three categories depending on the part of the plant from which they are extracted.

1. Bast or Stem fibres (jute, mesta, banana etc.)
2. Leaf fibres (sisal, pineapple, screw pine etc.)
3. Fruit fibres (cotton, coir, oil palm etc.).

II. STRUCTURE AND PROPERTIES OF SISAL FIBRE:

Sisal fibre is obtained from the leaves of the plant Agave sisalana, which was originated from Mexico and is now mainly cultivated in East Africa, Brazil, Haiti, India and Indonesia (Nilsson, 1975; Mattoso et al., 1997). It is grouped under the broad heading of the "hard fibres" among which sisal is placed second to manila in durability and strength (Weindling, 1947). The name "sisal" comes from a harbor town in Yucatan, Maya, Mexico (Nilsson, 1975). It means cold water. Agave plants were grown by the Maya Indians before the arrival of the Europeans. They prepared the fibres by hand and used it for ropes, carpets and clothing. Some clothes were called "nequen", and this is where the present name of Mexican agave, henequen, probably originates. It is one of the most extensively cultivated hard fibre in the world and it accounts for half the total production of textile fibres (Lock, 1962; Wilson, 1971). The reason for this is due to the ease of cultivation of sisal plants, which have short renewing times, and is fairly easy to grow in all kinds of environments. A good sisal plant yields about 200 leaves with each leaf having a mass composition of 4% fibre, 0.75% cuticle, 8% other dry matter and 87.25% moisture. Thus a normal leaf weighing about 600g yields about 3% by weight of fibre with each leaf containing about 1000 fibres (Kallapur, 1962). The fibre is extracted from the leaf either by retting, by scraping or by retting followed by scraping or by mechanical means using decorticators (KVIC, 1980). The diameter of the fibre varied from 100µm to 300µm (Mukherjee & Satyanarayana, 1984). The structure and properties of sisal fibre have been investigated by several researchers (Barkakaty, 1976; McLaughlin, 1980; Kulkarni et al., 1981; Gram, 1983; Mukherjee & Satyanarayana, 1984; Mattoso et al., 1997). Such understanding of structure –property relationship will not only help open up new avenues for these fibres, but also emphasize the importance of this agricultural material, which form one of the abundantly available renewable resources in the world. The characteristics of the sisal fibres depend on the properties of the individual constituents, the fibrillar structure and the lamellae matrix. The fibre is composed of numerous elongated fusiform fibre cells that taper towards each end. The fibre cells are linked together by means of middle lamellae, which consist of hemicellulose, lignin and pectin.

According to Gram (1983), a sisal fibre in cross-section is built up of about 100 fibre cells. Kulkarni et al. (1981) state that the number of cells in cross-section of a coconut fibre ranges from 260 to 584 depending on the diameter of the fibre.

The cross section of sisal fibres is neither circular nor fairly uniform in dimension. The lumen varies in size but is usually well defined. The longitudinal shape is approximately cylindrical. Physically, each fibre cell is made up of four main parts, namely the primary wall, the thick secondary wall, the tertiary wall and the lumen. Figure 3 shows a schematic sketch of a fibre cell. The cell walls consist of several layers of fibrillar structure consisting of fibrillae. In the primary wall, the fibrillae have a reticulated structure. In the outer secondary wall, which is located inside the primary wall, the fibrillae are arranged in spirals with a spiral angle of 40^o (for sisal fibre) in relation to the longitudinal axis of the cell. The fibrillae in the inner secondary wall of sisal fibres have a sharper slope, 18 to 25^o. The thin, innermost, tertiary wall has a parallel fibrillar structure and encloses the lumen. The fibrillae are, in turn, built up of micro-fibrillae with a thickness of about 20 nm. The microfibrillae are composed of cellulose molecular chains with a thickness of 0.7 nm and a length of a few µm (Gram, 1983).

III. EXPERIMENTAL PROCEDURE

2.1 Materials:

The semi retted sisal fibers were purchased from Nachoris Enterprises,Chennai, India.PLA (3001D) granules were purchased from Green Chemicals Ltd., Republic of Korea.

2.2 Composite Fabrication

The PLA granules were melted in the vertical injection molding machine with two heating zones. The operating temperature of the PLA is 190- 230^0C. The samples are prepared by taking different weight proportions (5%, 10%, 15%, 20% & 25%) of fiber content with PLA matrix. The samples of sisal/PLA composites were prepared by injection molding technique as per ASTM Standard size. The samples were air cooled at room temperature.

2.3 Flexural Test

Flexural Tests were conducted according to ASTM D790 using a 2 ton capacity - Electronic Tensometer, METM 2000 ER-I model, supplied by M/S Microtech Pune, with a cross head speed of 2mm/min.

IV. RESULTS AND DISCUSSION

The flexural strength and modulus of sisal fiber/PLA as a function of the sisal fiber content are presented in figure 3.1&3.2. ***From figures*** 3.1&3.2, it was observed that the flexural strength & modulus of composite increased with increase in the fibre loading up to 20% weight and then strength decreases with further increase in the fibre loading. This result may be due to the fact that, the incorporation of fibres into thermoplastics leads to poor dispersion of fibres due to strong inter fibre hydrogen bonding which holds the fibres together.

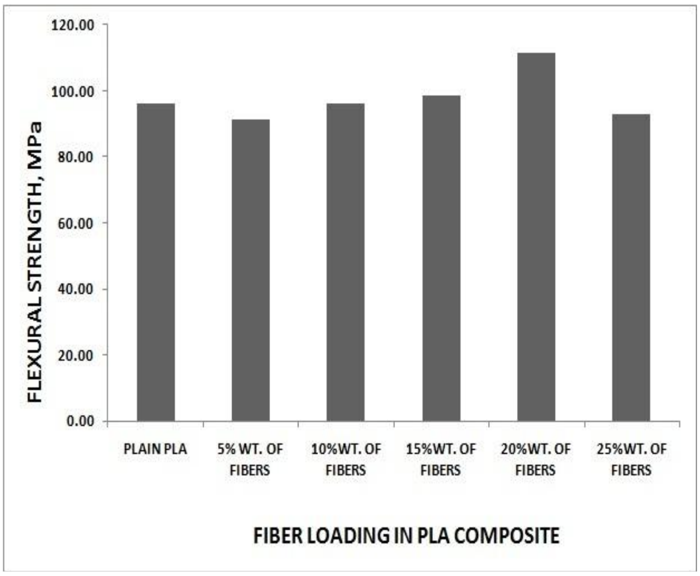

Figure 3.1: Variation of flexural strength of sisal fiber reinforced PLA composite with fiber loading.

Improper adhesion obstructs the increment of flexural strength. Thus as fibre percentage increases, gathering of fibers takes place instead of dispersion and melted PLA cannot wet the fibres due to non entrance of melt through the two adjacent fibres. Since there is more fibre- fibre interaction than fibre matrix interaction, failure occurs.

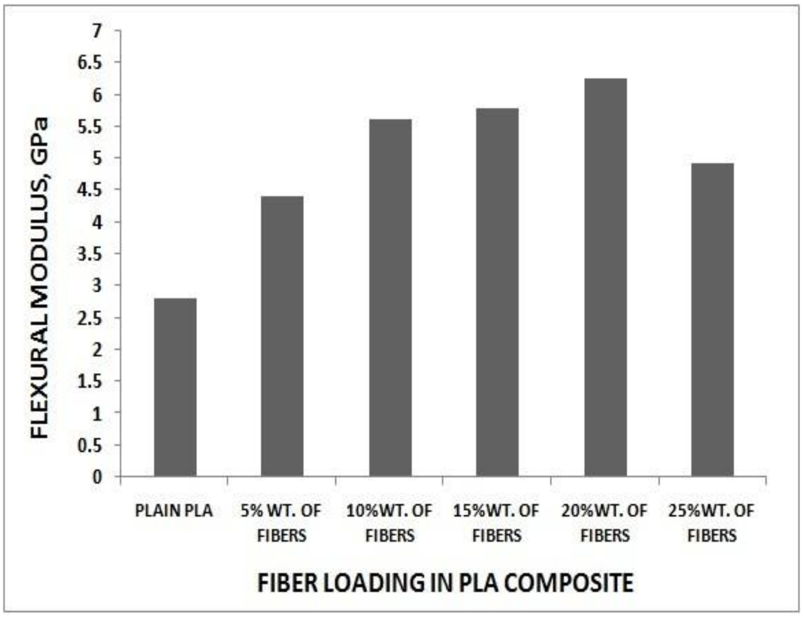

Figure 3.2: Variation of flexural modulus of sisal fiber reinforced PLA composite with fiber loading.

V. CONCLUSIONS

- Bio composite made of PLA reinforced with sisal fiber has been successfully fabricated by injection moulding process.
- There was increase in the flexural properties of the composite with increase in the fibre loading up to 20% and then reduced.
- PLA-Sisal bio composite has the potential as an ecologically beneficial alternative to natural reinforced composites with petroleum based matrices in the future.
- Sisal fiber has proven to be a good reinforcement for PLA by enhancing the flexural strength and modulus.

References

[1]. Xue Li Æ Lope G. Tabil Æ Satyanarayan Panigrahi: Chemical Treatments of Natural Fiber for Use in Natural Fiber-Reinforced Composites: A Review: J Polym Environ (2007) 15:25–33.

[2]. X. Y. Liu, G. C. Dai.: Surface modification and micromechanical properties of jute fiber mat reinforced polypropylene composites: eXPRESS Polymer Letters Vol.1, No.5 (2007) 299–307

[3]. Eastham J. : Natural fibres for the automotive industry in 'Seminar of The Alternative Crops Technology Interaction Network, Manchester, UK' **16**, 142–146 (2001).

[4]. Han S. O., Defoort B., Drzal L. T., Askeland P. A.: Environmentally friendly biocomposites for automotive applications in '33rd ISTC Conference, Seattle, USA' **33**, 1466–1477 (2001).

[5]. Marsh G.: Next step for automotive materials. Materials Today, **6**, 36-43 (2003).

[6]. Chen Y., Chiparus O., Sun L., Negulescu I., Parikh D. V., Calamari T. A.: Natural fibers for automotive nonwoven composites. Journal of Industrial Textiles, **35**, 47–62 (2005).

[7]. Gassan J., Bledzki A. K.: Possibilities for improving the mechanical properties of jute/epoxy composites by alkali treatment of fibres. Composites Science and Technology, 59, 1303–1309 (1999).

[8]. Gassan J., Bledzki A. K.: Effect of cyclic moisture absorption desorption on the mechanical properties of silanized jute-epoxy composites. Polymer Composites, 20, 604–611 (1999).

[9]. Gassan J., Gutowski V. S.: Effects of corona discharge and UV treatment on the properties of jute-fibre epoxy composites. Composites Science and Technology, 60, 2857–2863 (2000).

[10]. Karmaker A. C., Youngquist J. A.: Injection moulding of polypropylene reinforced with short jute fibers. Journal of Applied Polymer Science, 62, 1147–1151 (1996).

[11]. Wei-ming Wang; Zai-sheng Cai; jian-yong Yu: Study on Chemical Modification Process of jute. Journal of Engineering fibers and fabrics Volume 3, Issue 2, 2008.

[12]. Mohd Zuhri Mohamed Yusoff; Mohd Sapuan Salit; Napsiah Ismail; Riza Wirawan: Mechanical Properties of short random oil palm fiber reinforced epoxy composites. Sains Malaysiana 39(1)(2010): 87-92.

[13]. Morsyleide F. Rosa, Bor-sen Chiou, Eliton S. Medeiros: Effect of fiber treatments on tensile and thermal properties of starch/ethylene vinyl alcohol copolymers/coir biocomposites: Bioresource Technology 100 (2009) 5196–5202.

[14]. Amel El Ghali, Imed Ben Marzoug: Separation and characterization of new cellulosic fibers from the Juncus acutus L Plant: Bio Resources 7(2), 2002-2018, 2002.

[15]. Md Nuruzzaman Khan, Juganta K. Roy, Nousin Akter, Haydar U. Zaman: Production and Properties of Short Jute and Short E-Glass Fiber Reinforced Polypropylene-Based Composites: Open Journal of Composite Materials, 2012, 2, 40-47.

[16]. Dipa Ray, B K Sarkar, A K Rana And N R Bose: Effect of alkali treated jute fibres on composite properties: Bull. Mater. Sci., Vol. 24, No. 2, April 2001, pp. 129–135.

[17]. H.M.M.A Rashed, M.A. Islam and F.B. Rizvi: Effects of process parameters on tensile strength of jute fiber reinforced thermoplastic composites. Journal of naval architechture and merine engineering, 3(2006) 1-6.

[18]. Beckerman G.W., Pickering, K.L., and foreman. N.J.: The Processing, Production and Improvement of hemp fibre reinforced polypropylene composite materials: proceedings of SPPM, 25-27 feb.2004. pp 257-265.
[19]. Dieu. T.V., Phai L.T.,Ngoc P.M.: Study on preparation of polymer composites based on polypropylene reinforced by jute fibers: JSME International journal, Series A: Solid mechanics & Material engineering, Vol. 47, No.4, pp 547-550.
[20]. Razera I.A.T., and Frollini.E.: Composites based on jute fibers and phenolic matrices: Properties of fibers and composites: Journal of applied polymer science Vol.91, No.2, pp 1077-1085.
[21]. Ray D., Sarkar B.K., Rana A.K., Bose N.R.: Effect of alkali treated jute fibres on composite properties, Bulletin of materials science, Vol.24, No.2, pp. 129-135.
[22]. M Alamgir Kabir, M. Monimul Huque: Mechanical Properties of Jute fibre reinforced Polypropylene composite: effect of benzenediazonium salt inalkaline medium: bio resources 5(3), 1618-1625.
[23]. S Jayabal, S Sathiyamurthy, K T Loganathan And S Kalyanasundaram. Effect of soaking time and concentration of NaOH solution on mechanical properties of coir–polyester composites: Bull. Mater. Sci., Vol. 35, No. 4, August 2012, pp. 567–574.